SUBSTITUTE SPECIFICATION

DIRECTIONAL COUPLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to directional couplers, and in particular, relates to a directional coupler that only couples microwaves that propagate through a transmission line in a first direction and obtains an output proportional to the microwave power and that does not couple microwaves that propagate through the transmission line in a second direction opposite to the first direction.

2. Description of the Related Art

[0002] For example, as described in Japanese Unexamined Patent Application Publication No. 5-160614, waveguide circuits, which have been the predominant microwave circuits, require high precision machining and thus are not suitable for mass production and are expensive. Moreover, a problem has existed with waveguide circuits in that the outer dimensions and weights of the waveguide circuits are large. Thus, microstrips, which can be reduced in size and weight through the use of large-scale integration technology have been used in radios, BS receivers, and the like.

[0003] A conventional directional coupler composed of

microstrips shown in Fig. 6 is disclosed in Japanese Unexamined Patent Application Publication No. 5-160614.

[0004] This directional coupler is a side-edge type coupler, which has a structure in which sections of respective stripline electrodes 81a and 82a of microstrips 81 and 82 are disposed close to each other for the length of $\lambda/4$ in the horizontal direction and the upper and lower surfaces of the microstrips 81 and 82 are covered with ground electrodes 83 and 84. In a coupled mode of the sections of the stripline electrodes 81a and 82a which are disposed close to each other, a first microwave power is input from a port 1 to the microstrip 81 functioning as a main line while a second microwave power, that is a fraction of the first microwave power, is generated in a port 3 of the microstrip 82 functioning as a subordinate line.

[0005] For example, as shown in Fig. 7, in a cellular phone unit, in order to keep the transmission power at a minimum level through the function of dividing high frequency signals into two components in the aforementioned directional coupler, a main line 70a of a directional coupler 70 is disposed between a transmission power amplifier 71 and an antenna 72 and one end of a subordinate line 70b is connected to an automatic gain control circuit 73 so that the automatic gain control circuit 73 adjusts the output of the transmission power amplifier 71.

[0006] With regard to cellular phone units and the like, an important issue is to minimize the size. Thus, the size of directional couplers has been required to be further reduced.

However, in the directional coupler shown in Fig. 6, for example, λ/4 is 7.5 cm (on the condition that the specific inductive capacity is 1) at 1 GHz. Thus, the required minimum length of the sections disposed close to each other in the horizontal direction of the stripline electrodes 81a and 82a is 7.5 cm. Accordingly, the size of the substrate, which includes the stripline electrodes 81a and 82a thereon, becomes large. Moreover, for example, when respective substrates that include the ground electrodes 83 and 84 thereon are disposed and fastened with screws under and over the substrate, which includes the stripline electrodes 81a and 82a thereon, a problem arises in that a reduction in size is limited and the cost increases.

[0007] Accordingly, a directional coupler that is improved to solve the aforementioned problem is proposed in Japanese Unexamined Patent Application Publication No. 5-160614. In this directional coupler, ground electrode substrates that include ground electrodes thereon are alternately laminated with dielectric substrates on which a pair of stripline electrodes are provided so that the stripline electrodes are disposed close and parallel to each other in a spiral shape. Then, the corresponding stripline electrode components of the individual dielectric substrates are connected in series with each other through a pair of via holes that are close to each other so that the stripline electrodes have the length of a quarter of a wavelength.

[0008] In the improved directional coupler, the stripline electrodes having the length of a quarter of a wavelength are formed with the stripline electrode components and the via holes so that the stripline electrodes are divided into components on a plurality of laminated dielectric substrates. Thus, the size of the improved directional coupler can be small compared with that of the directional coupler shown in Fig. 6. However, even in the improved directional coupler, the total length of the stripline electrodes is required to be a quarter of a wavelength. Thus, the size of the directional coupler cannot be significantly reduced. Moreover, in general, side-edge type couplers have a problem in that it is difficult to achieve a high degree of coupling due to the characteristics of the distribution of a magnetic field around the stripline electrodes. The improved directional coupler uses side-edge coupling between a pair of stripline electrodes. Thus, the improved directional coupler has a problem in that it is difficult to achieve a high degree of coupling.

[0009] On the other hand, a directional coupler called a broad-side type coupler is proposed in Japanese Patent No. 3203253. In this directional coupler, spiral-shaped coupled lines are opposed to each other with dielectric layers therebetween so as to achieve coupling between the coupled lines. Since the inductance value of the coupled lines becomes high in the directional coupler, the directional coupler can be constructed with lines that are shorter than a quarter of a

wavelength. Thus, the size can be readily reduced, and a high degree of coupling can be achieved with a small loss.

[0010] However, in the directional coupler disclosed in Japanese Patent No. 3203253, since spiral-shaped coupled lines are opposed to each other with dielectric layers therebetween so as to achieve coupling between the coupled lines, the capacitance between the coupled lines becomes large. Thus, the directional coupler has a problem in that high isolation between the coupled lines cannot be achieved.

[0011] Moreover, in the directional couplers disclosed in Japanese Unexamined Patent Application Publication No. 5-160614 and Japanese Patent No. 3203253, coupling is adjusted by adjusting the distance between lines. In this case, a magnetic field and an electric field around the lines are both changed by adjusting the distance between the lines, and it is impossible to adjust only one of the magnetic field and the electric field. Thus, it is difficult to adjust isolation. Isolation is a phenomenon in which magnetic field coupling and electric field coupling nullify each other. Thus, isolation has been adjusted only by selecting types of materials of substrates on which coupled lines are provided to change the permittivity and the permeability.

SUMMARY OF THE INVENTION

[0012] In order to overcome the problems described above, preferred embodiments of the present invention provide a small

directional coupler that has a high coupling value and high isolation characteristics.

[0013] In order to achieve this, a directional coupler according to a first preferred embodiment of the present invention includes at least one dielectric layer and two line electrodes that are provided on the at least one dielectric layer. The two line electrodes include an inner line electrode and an outer line electrode that surrounds the inner line electrode, as viewed from above. Corresponding currents are transmitted in the same direction through sections of the inner line electrode and the outer line electrode that are adjacent and parallel to each other.

[0014] In the directional coupler according to the first preferred embodiment of the present invention, since the corresponding currents are transmitted in the same direction through the sections of the inner line electrode and the outer line electrode, which are adjacent and parallel to each other, the inductance values of the line electrodes become high. Thus, inductive coupling between the inner line electrode and the outer line electrode becomes strong, and capacitive coupling between the inner line electrode and the outer line electrode becomes weak, thereby achieving high isolation. Moreover, high inductance values can be achieved while the size of the directional coupler is small, and thus the size of the directional coupler can be reduced. Moreover, the inductance values of the inner line electrode and the outer line electrode

can be readily adjusted so that the inductance values agree with each other by adjusting the respective numbers of turns of the inner line electrode and the outer line electrode.

[0015] A directional coupler according to a second preferred embodiment of the present invention includes at least one dielectric layer and two line electrodes that are provided on the at least one dielectric layer. The two line electrodes include a spiral-shaped or helical-shaped inner line electrode and a spiral-shaped or helical-shaped outer line electrode that surrounds the inner line electrode, as viewed from above.

[0016] In the directional coupler according to the second preferred embodiment of the present invention, the inner line electrode and the outer line electrode are formed so as to have a spiral or helical shape. Thus, the corresponding currents are transmitted in the same direction through the sections of the inner line electrode and the outer line electrode, which are adjacent and parallel to each other, and the inductance values of the line electrodes become high. Thus, inductive coupling between the inner line electrode and the outer line electrode becomes strong, and capacitive coupling between the inner line electrode and the outer line electrode becomes weak, thereby achieving high isolation. Moreover, high inductance values can be achieved while the size of the directional coupler is small, and thus the size of the directional coupler can be reduced. Moreover, the inductance values of the inner line electrode and the outer line electrode can be readily adjusted so that the

inductance values agree with each other by adjusting the respective numbers of turns of the inner line electrode and the outer line electrode.

[0017] In the directional couplers according to the first and second preferred embodiments of the present invention, since the degree of inductive coupling between the inner line electrode and the outer line electrode is high, the length of each of the inner line electrode and the outer line electrode can be kept to less than a quarter of a wavelength. Thus, the size of the directional coupler can be further reduced.

[0018] Moreover, in the directional couplers according to the first and second preferred embodiments of the present invention, it is preferable that the width of the inner line electrode is smaller than the width of the outer line electrode. When the width of the inner line electrode is reduced, the inductance value of the inner line electrode is increased. Accordingly, even when the number of turns of the inner line electrode is reduced, the inductance values of the inner line electrode and the outer line electrode can be adjusted so that the inductance values agree with each other. Thus, the size of the directional coupler can be further reduced.

[0019] Moreover, the number of turns of the inner line electrode may be larger than the number of turns of the outer line electrode. The inductance values of the inner line electrode and the outer line electrode can be readily adjusted so that the inductance values agree with each other by

increasing the number of turns of the inner line electrode.

[0020] Moreover, the inner line electrode and the outer line electrode may be provided on the same plane. A first area of the spiral-shaped or helical-shaped outer line electrode opposing the spiral-shaped or helical-shaped inner line electrode, which first area is located inside the outer line electrode, is substantially the same as a second area of the inner edge of the innermost circumferential of the outer line electrode opposing the outer edge of the outermost circumferential of the inner line electrode. Thus, only certain sections of the inner line electrode oppose sections of the outer line electrode in the first area. Moreover, the thickness of the inner line electrode and the outer line electrode is fairly small. Thus, the capacitance between the inner line electrode and the outer line electrode is small, and the degree of isolation between these line electrodes can be significantly increased.

[0021] Moreover, the inner line electrode and the outer line electrode may be provided on different planes. The capacitance between the inner line electrode and the outer line electrode can be further reduced by providing the inner line electrode and the outer line electrode on different planes. Thus, the degree of isolation between these line electrodes can be further increased.

[0022] Moreover, at least one of the inner line electrode and the outer line electrode may be divided into line electrode

components that are provided on a plurality of planes, and the divided line electrode components may be connected in series with each other through a via hole. When the inner line electrode and/or the outer line electrode are divided into line electrode components that are provided on a plurality of planes, the number of line electrode components per unit area that are provided on one plane can be reduced. Thus, the size of the directional coupler can be further reduced.

[0023] Moreover, the directional coupler according to preferred embodiments of the present invention may further include a ground electrode that is provided on the dielectric layer. Capacitances may be formed between the ground electrode and individual ends of the inner line electrode and the outer line electrode. Due to the functions of the capacitances formed between the ground electrode and the individual ends of the inner line electrode and the outer line electrode, the resonant frequencies of the inner line electrode and the outer line electrode can be reduced. Thus, the size of the directional coupler can be further reduced by shortening the lengths of the line electrodes to obtain a predetermined resonant frequency.

[0024] Other features, elements, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Fig. 1 is a perspective view showing the external appearance of a directional coupler according to a first preferred embodiment of the present invention.

[0026] Fig. 2 is an exploded perspective view showing the structure of the directional coupler shown in Fig. 1.

[0027] Fig. 3 is an exploded perspective view of a directional coupler according to a second preferred embodiment of the present invention.

[0028] Fig. 4 is an exploded perspective view of a directional coupler according to a third preferred embodiment of the present invention.

[0029] Fig. 5 is an exploded perspective view of a directional coupler according to a fourth preferred embodiment of the present invention.

[0030] Fig. 6 shows a conventional directional coupler.

[0031] Fig. 7 is a block diagram showing an RF transmitter circuit in which a directional coupler is used.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0032] Directional couplers according to preferred embodiments of the present invention will now be described with reference to the attached drawings.

First Preferred Embodiment

[0033] Figs. 1 and 2 show the external appearance and the exploded structure of a directional coupler 10a according to a first preferred embodiment of the present invention, respectively. The directional coupler 10a includes a chip laminate body 16 including a first ground electrode substrate 11, a dielectric substrate 12 that includes an inner line electrode 21a and an outer line electrode 22a that have a spiral shape on one major surface thereof, a lead-out conductor substrate 13 that includes lead-out conductors 23a, 24a, and 25a of the inner line electrode 21a and the outer line electrode 22a provided thereon, a second ground electrode substrate 14, and a protection substrate 15.

[0034] External electrodes G for grounding, external electrodes P_1 and P_2 for a main line, and external electrodes P_3 and P_4 for a subordinate line are provided on side surfaces of the laminate body 16 so as to extend from the first ground electrode substrate 11 to the protection substrate 15.

[0035] The substrates 11, 12, 13, 14, and 15 are composed of ceramic green sheets that are formed of dielectric ceramic materials by using, for example, the doctor blade method or the Czochralski method, and are laminated into the laminate body 16 and sintered.

[0036] Thus, in practice, in Fig. 1, a separating line does not appear between the substrates 11, 12, 13, 14, and 15 in the direction in which these substrates are laminated. The aforementioned external electrodes G, P_1, P_2, P_3, and P_4 may be

formed after the laminate body 16 has been sintered.

[0037] A ground electrode 17 is provided on the major surface of the first ground electrode substrate 11. The size of the ground electrode 17 is such that the ground electrode 17 completely covers the inner line electrode 21a and the outer line electrode 22a, which have a spiral shape and are provided on the dielectric substrate 12, excluding the peripheral region of the major surface of the first ground electrode substrate 11. The ground electrode 17 is connected to the external electrodes G, G for grounding through lead-out portions 17a, 17a.

[0038] The inner line electrode 21a functioning as a main line and the outer line electrode 22a functioning as a subordinate line are provided by printing on the major surface of the dielectric substrate 12 at a stage in which the dielectric substrate 12 is a green sheet that has not been sintered. In the first preferred embodiment, the inner line electrode 21a and the outer line electrode 22a preferably have substantially the same width, and the respective numbers of turns of the inner line electrode 21a and the outer line electrode 22a are 2.5 and 1.5, respectively. The line length of each of the main and subordinate lines is less than a quarter of a wavelength.

[0039] The lead-out conductors 23a, 24a, and 25a are provided on the major surface of the lead-out conductor substrate 13. The inner end of the inner line electrode 21a having a spiral shape is connected to the external electrode P_1 for the main line

through a via hole Vh_1 and the lead-out conductor 23a, which are provided in the lead-out conductor substrate 13, and the outer end of the inner line electrode 21a is connected to the external electrode P_2 for the main line through a via hole Vh_2 and the lead-out conductor 24a, which are provided in the lead-out conductor substrate 13.

[0040] The inner end of the outer line electrode 22a having a spiral shape is connected to the external electrode P_3 for the subordinate line through a via hole Vh_3 and the lead-out conductor 25a, which are provided in the lead-out conductor substrate 13, and the outer end of the outer line electrode 22a is connected directly to the external electrode P_4 for the subordinate line on the dielectric substrate 12.

[0041] A ground electrode 18 is provided on the major surface of the second ground electrode substrate 14 laminated on the lead-out conductor substrate 13. The size of the ground electrode 18 is such that the ground electrode 18 completely covers the two line electrodes 21a and 22a, which have a spiral shape and are provided on the dielectric substrate 12, excluding the peripheral region of the major surface of the second ground electrode substrate 14. The ground electrode 18 is connected to the external electrodes G for grounding through lead-out portions 18a. The ground electrode 18 is covered with the protection substrate 15 which is laminated on the second ground electrode substrate 14.

[0042] In the directional coupler 10a having the

aforementioned structure, the outer line electrode 22a having a spiral shape and the inner line electrode 21a having a spiral shape are coupled by side-edge coupling therebetween. The inner line electrode 21a is surrounded by the outer line electrode 22a and disposed inside the outer line electrode 22a. An enclosed area between the inner line electrode 21a and the outer line electrode 22a is substantially the same as an enclosed area between the inner edge of the innermost circumferential of the outer line electrode 22a and the outer edge of the outermost circumferential of the inner line electrode 21a. Thus, only certain sections of the inner line electrode 21a oppose sections of the outer line electrode 22a in the first area. Moreover, since the inner line electrode 21a and the outer line electrode 22a are formed by printing, the thickness of each line electrode is thin. Thus, the capacitance formed between the inner line electrode 21a and the outer line electrode 22a is small, and high isolation between these line electrodes can be achieved.

[0043] Moreover, in the directional coupler 10a, the inner line electrode 21a and the outer line electrode 22a have a spiral shape. In Fig. 2, for example, the corresponding currents are transmitted through parallel front left sections of the inner line electrode 21a and the outer line electrode 22a in the same direction, as indicated by arrow A. Thus, the inductance values of the line electrodes 21a and 22a become high at sections of the inner line electrode 21a and the outer line electrode 22a. Accordingly, inductive coupling between the

inner line electrode 21a and the outer line electrode 22a becomes strong and capacitive coupling between the inner line electrode 21a and the outer line electrode 22a becomes weak. Moreover, the inductance values of the inner line electrode 21a and the outer line electrode 22a can be readily adjusted so that the inductance values agree with each other by adjusting the respective numbers of turns of the inner line electrode 21a and the outer line electrode 22a.

[0044] In the directional coupler 10a, the inner line electrode 21a and the outer line electrode 22a have a spiral shape, and the corresponding currents are transmitted through the sections of the inner line electrode 21a and the outer line electrode 22a that are parallel and adjacent to each other in the same direction. Thus, a high inductance value can be achieved while the size of the directional coupler 10a is small. The length of each line electrode can be less than a quarter of a wavelength, and the size of the directional coupler 10a can be reduced.

[0045] In the aforementioned description of the directional coupler 10a, the inner line electrode 21a is the main line electrode and the outer line electrode 22a is the subordinate line electrode. Even when the inner line electrode 21a is the subordinate line and the outer line electrode 22a is the main line, the directional coupler 10a can operate in the same manner. The same applies to the remaining preferred embodiments, which are described below.

Second Preferred Embodiment

[0046] Fig. 3 shows a directional coupler 10b according to a second preferred embodiment of the present invention. While the dielectric substrate 12 is used in the directional coupler 10a according to the first preferred embodiment, which was described with reference to Figs. 1 and 2, wherein the inner line electrode 21a and the outer line electrode 22a preferably have substantially the same width on the dielectric substrate 12; a dielectric substrate 12a is used in the directional coupler 10b, an inner line electrode 21b and an outer line electrode 22b are provided on the dielectric substrate 12a so that the width of the inner line electrode 21b is narrower than that of the outer line electrode 22b.

[0047] When the width of the inner line electrode 21b is narrower, the inductance value of the inner line electrode 21b is increased. Accordingly, the number of turns of the inner line electrode 21b can be reduced. Thus, a directional coupler 10b that is smaller than the directional coupler 10a can be obtained.

[0048] In Fig. 3, the same reference letters and numerals as in Fig. 2 are assigned to the corresponding components, and duplicate description thereof is omitted. The advantages achieved by the second preferred embodiment are basically the same as those achieved by the first preferred embodiment.

Third Preferred Embodiment

[0049] Fig. 4 shows a directional coupler according to a third preferred embodiment of the present invention. While the dielectric substrate 12 is used in the directional coupler 10a according to the first preferred embodiment, which was described with reference to Figs. 1 and 2, wherein the inner line electrode 21a and the outer line electrode 22a preferably have substantially the same width on the dielectric substrate 12; dielectric substrates 32, 33, and 34 are used in the directional coupler 10c. Three inner line electrode components 21aa, 21ab, and 21ac, into which the inner line electrode is divided, are respectively provided on the dielectric substrates 32, 33, and 34; and two outer line electrode components 22aa and 22ab, into which the outer line electrode is divided, are respectively provided on the dielectric substrates 32 and 33. When this arrangement is utilized, the inner line electrode and the outer line electrode are formed as helical lines.

[0050] In Fig. 4, the same reference letters and numerals as in Fig. 2 are assigned to the corresponding components, and duplicate description thereof is omitted.

[0051] One end of the inner line electrode component 21aa is connected through a via hole Vh_{11} in the dielectric substrate 32 to a lead-out conductor 23b on a lead-out conductor substrate 31 and the external electrode P_1 for the main line. The other end of the inner line electrode component 21aa is connected through a via hole Vh_{12} in the dielectric substrate 33 to one end of the

inner line electrode component 21ab on the dielectric substrate 33.

[0052] The other end of the inner line electrode component 21ab is connected through a via hole Vh_{13} in the dielectric substrate 34 to one end of the inner line electrode component 21ac on the dielectric substrate 34. The other end of the inner line electrode component 21ac is connected directly to the external electrode P_2 for the main line on the dielectric substrate 34.

[0053] On the other hand, one end of the outer line electrode component 22aa is connected directly to the external electrode P_3 for the subordinate line on the dielectric substrate 32. The other end of the outer line electrode component 22aa is connected through a via hole Vh_{14} in the dielectric substrate 33 to one end of the outer line electrode component 22ab on the dielectric substrate 33. The other end of the outer line electrode component 22ab is connected directly to the external electrode P_4 for the subordinate line on the dielectric substrate 33.

[0054] Even when this arrangement is utilized, the same advantages as in the directional coupler 10a, which was described with reference to Figs. 1 and 2, can be achieved. As is apparent from Fig. 4, the inner line electrode is divided into the three inner line electrode components 21aa, 21ab, and 21ac, and the outer line electrode is divided into the two outer line electrode components 22aa and 22ab. Thus, the number of

line electrode components per unit area that are on the dielectric substrates 32, 33, and 34 can be reduced, and the size of the directional coupler can be further reduced.

Fourth Preferred Embodiment

[0055] Fig. 5 shows a directional coupler 10d according to a fourth preferred embodiment of the present invention. In the directional coupler 10d, the inner line electrode is divided into three inner line electrode components 21aa, 21ab, and 21ac, and the outer line electrode is divided into three outer line electrode components 22aa, 22ab, and 22ac, as in the directional coupler 10c according to the third preferred embodiment, which was described with reference to Fig. 4. These line electrode components are provided on three dielectric substrates 57, 58, and 59. Capacitances are formed between the external electrodes P_1 to P_4 for the main and subordinate lines and the external electrodes G for grounding.

[0056] One end of the inner line electrode component 21aa is connected through a via hole Vh_{21} in the dielectric substrate 57 to a lead-out conductor 23c on a lead-out conductor substrate 56 and the external electrode P_1 for the main line. The other end of the inner line electrode component 21aa is connected through a via hole Vh_{22} in the dielectric substrate 58 to one end of the inner line electrode component 21ab on the dielectric substrate 58. The other end of the inner line electrode component 21ab is connected through a via hole Vh_{23} in the dielectric substrate 59

to one end of the inner line electrode component 21ac on the dielectric substrate 59. The other end of the inner line electrode component 21ac is connected directly to the external electrode P_2 for the main line on the dielectric substrate 59.

[0057] On the other hand, one end of the outer line electrode component 22aa is connected through a via hole Vh_{24} in the dielectric substrate 57 to a lead-out conductor 26 on the lead-out conductor substrate 56 and the external electrode P_4 for the subordinate line. The other end of the outer line electrode component 22aa is connected through a via hole Vh_{25} in the dielectric substrate 58 to one end of the outer line electrode component 22ab on the dielectric substrate 58. The other end of the outer line electrode component 22ab is connected through a via hole Vh_{26} in the dielectric substrate 59 to one end of the outer line electrode component 22ac on the dielectric substrate 59. The other end of the outer line electrode component 22ac is connected directly to the external electrode P_3 for the subordinate line on the dielectric substrate 59.

[0058] A dummy substrate 55a is laminated between the lead-out conductor substrate 56 and the ground electrode substrate 11, and a dummy substrate 55b is laminated between the dielectric substrate 59 and the ground electrode substrate 14. In the directional coupler 10d, capacitor electrode substrates 51 to 54 for forming capacitances are laminated, in this order from the bottom, under the ground electrode substrate 11.

[0059] A capacitor electrode 61 is provided on the major

surface of the capacitor electrode substrate 51. The capacitor electrode 61 is arranged so that the capacitor electrode 61 covers a substantially entire area of the major surface of the capacitor electrode substrate 51, excluding the peripheral region of the major surface of the capacitor electrode substrate 51. The capacitor electrode 61 is connected to the external electrodes G, G for grounding through lead-out portions 61a, 61a. Two strip-shaped capacitor electrodes 63b and 64b are provided on the major surface of the capacitor electrode substrate 52. The capacitor electrodes 63b and 64b are connected to the external electrodes P_4 and P_3 for the subordinate line, respectively.

[0060] A capacitor electrode 62 is provided on the major surface of the capacitor electrode substrate 53. The capacitor electrode 62 is arranged so that the capacitor electrode 62 covers substantially the entire area of the major surface of the capacitor electrode substrate 53, excluding the peripheral region of the major surface of the capacitor electrode substrate 53. The capacitor electrode 62 is connected to the external electrodes G, G for grounding through lead-out portions 62a, 62a. Two strip-shaped capacitor electrodes 63a and 64a are provided on the major surface of the capacitor electrode substrate 54. The capacitor electrodes 63a and 64a are connected to the external electrodes P_1 and P_2 for the main line, respectively.

[0061] The advantages achieved by the fourth preferred

embodiment are the same as those achieved by the first preferred embodiment. Moreover, when the aforementioned arrangement is utilized, capacitances are formed between the capacitor electrodes 63a and 64a, the capacitor electrode 62, and the ground electrode 17; and between the capacitor electrodes 63b and 64b, the capacitor electrode 61, and the capacitor electrode 62. Due to the functions of these capacitances, the resonant frequencies of the inner line electrode, which is divided into the three inner line electrode components 21aa, 21ab, and 21ac, and the outer line electrode, which is divided into the three outer line electrode components 22aa, 22ab, and 22ac, can be reduced. Thus, the size of the directional coupler 10d can be further reduced by shortening the lengths of the line electrodes to obtain a predetermined resonant frequency.

Other Preferred Embodiments

[0062] Directional couplers according to the present invention are not limited to the aforementioned preferred embodiments and can have various structures within the gist and scope of the present invention.

[0063] For example, in the directional coupler 10a, although not specifically shown in the drawings, the inner line electrode 21a may be provided on one dielectric substrate, and the outer line electrode 22a may be provided on another dielectric substrate. In this arrangement, the capacitance between the inner line electrode 21a and the outer line electrode 22a can be

reduced, resulting in high isolation between these line electrodes.

[0064] The present invention may be applied to directional couplers for a microwave band as described above, and in particular, is excellent in that a high coupling value and high isolation characteristics can be achieved.

[0065] While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.